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OFFICE OF
PREVENTION, PESTICIDES AND
TOXIC SUBSTANCES

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MEMORANDUM

SUBJECT: PRZM Standard Crop/Location Scenarios, Procedure to Develop and Approve New Scenarios, and PRZM Turf Modeling Scenarios to Date

FROM: Elizabeth Leovey, Acting Director
Environmental Fate and Effects Division

TO: EFED Staff and Managers

Modeling pesticide exposures from use on various crops across the U.S. has resulted in the development of a fairly robust library of PRZM field crop scenarios. Often these scenarios were created using minimal guidance and best professional judgement of the scientist. Although this approach to scenario development has served EFED well in the past, there are now many scenarios being developed and the time has come to establish a set of procedures to ensure consistent exposure and risk assessments for all pesticides. EFED's OP Cumulative development team identified the lack of a documented process as a potential criticism of its drinking water exposure assessment. During the developme... f the OP Cumulative Risk Assessment, a subgroup of the Water Quality Technical Team pursued standardizing a number of PRZM field crop scenarios using a set of procedures (QA_QC Documentation Ver2.wpd) to ensure consistency in the way crop scenarios are developed. The initial focus in applying these procedures to the suite of existing scenarios was to address the needs of the OP Cumulative Risk Assessment effort. Additional scenarios have been subjected to these procedures following the completion of the cumulative risk assessment. A listing of the scenarios that have undergone these procedures can be found in Table 1. The remaining scenarios (Table 2) are available for use, but must first be subjected to the QA/QC procedures.

This memorandum is intended to notify staff of the availability of approved standard scenarios that can now be used and those awaiting standardization and should not be used. In addition, information on where each set of scenarios can be found, how staff will be notified of the availability of newly QA/QC'd scenarios, how the *approved* standard scenarios can be used, and the supporting information used in their development and standardization is provided. Finally, the results of efforts to develop a Tier 2 turf scenario by the Turf Modeling subgroup of the Water Quality Technical Team (WQTT) are presented.

Approved PRZM Field Crop Scenarios

Table 1 provides a list of all PRZM scenarios approved to date using QA/QC procedures developed and peer reviewed by the WQTT. These scenarios are available as "text "(.txt) files on the LAN:

F:\USER\SHARE\Models\Aquatic Exposure\PRZMEXAMS\Scenarios\STD_SCEN\QA_QC Standard Scenarios.

Only scenarios on this list may be used for aquatic exposure assessments without further peer review of the specific crop/region aspects of the scenario.

As new scenarios are developed and QA/QC'd, they will be added to the above LAN directory and the attached list of scenarios (Table 1) will be updated and forwarded to scientists and managers in EFED. In addition, the co-chairs of the Water Quality Technical Team will be asked to announce the updated list at the meeting following the posting of a new scenario. The list of available scenarios will be maintained on the LAN. Plans are underway to develop a CD-ROM with all approved models and scenarios to be distributed to the branch chief, senior scientists and others as appropriate. When completed, the WQTT co-chairs will notify EFED staff through a separate memorandum.

Each scenario residing on the LAN is designed to be used directly with EFED's Graphical Interface (developed by Ian Kennedy) as its "text" file without modification. In addition, with conversion to the standard input file, either using the graphical interface to generate the input file or through manual conversion, all scenarios can be used with the traditional DOS-based PRZM model. However, the user must follow the guidance for developing an Index Reservoir (*F:\USER\SHARE\Policies, Guidance, and Formats\EFED Policies\Policies by Topic\Index Reservoir and PCA*) for use in modeling drinking water exposures.

The crop/region specificity of the scenarios may require an exposure assessor to run all regional scenarios for a given crop depending on the need to capture the most conservative set of results. At this time, an analysis of the most conservative region for a given crop has not been formerly conducted. In some cases, such as citrus, it is clear that the Florida scenario will yield higher estimated environmental concentrations when compared to California based on the differences in precipitation and soil characteristics. Plans are underway to assess the most conservative standard scenario for a given crop, where appropriate. The results of this analysis will be communicated to you in a follow-up memorandum.

As part of the documentation of each scenario, a metadata file (OP Scenario Metadata DF 111401.wpd) has been created for your use. A complete description of each crop scenario, scenario parameter, and its reference can be found on the LAN:

F:\USER\SHARE\Models\Aquatic Exposure\PRZMEXAMS\Scenarios\STD_SCEN\Standard Scenario Documentation

A complete discussion of the purpose and methods of scenario standardization can be found in the Preliminary OP Cumulative Risk Assessment as an appendix located on the following web page: (http://www.epa.gov/pesticides/cumulative/pra-op/).

Non Approved PRZM Field Crop Scenarios

Table 2 provides the list of the known scenarios developed in the past, but are in need of the QA/QC review. These scenarios are located on the LAN:

F:\USER\SHARE\Models\Aquatic Exposure\PRZMEXAMS\Scenarios\STD_SCEN\Non-QA_QC Scenarios.

These scenarios should not be used in an aquatic exposure assessment without first going through the QA/QC procedures. Only under time sensitive situations should one of these scenarios be used and only with a clear articulation of the uncertainties associated with the lack of formal procedures to standardized and peer review the crop/regional aspects of the scenario.

On several occasions over the past two years the co-chairs of the WQTT have requested modelers to submit their crop scenarios for cataloging. If after reviewing this list you are aware of, and have a copy of, additional scenarios, you are encouraged to pass them on to the Scenario QA/QC Team for posting and eventual standardization, point of contact is Sid Abel.

Each nonstandard scenario was developed using the modeler's best professional judgement. Effective with the receipt of this memorandum, these scenarios must be revised according to standard procedures followed by a QA/QC review. These procedures are available on the LAN:

F:\USER\SHARE\Models\Aquatic Exposure\PRZMEXAMS\Scenarios\STD_SCEN\Standard Scenario Documentation

In most cases, an existing nonstandard scenario will require little change, but will require substantially more documentation of scenario parameters. Best estimates of resources needed to modify and peer review a given scenario is from 2-4 elapsed days. Staff needing one of the existing nonstandard scenarios should plan accordingly.

New scenarios can be developed in as little as 2-4 days as well using the same standardization procedures. Numerous web-based resources and state contacts for locating readily available peer reviewed information is provided in the document to assist you when reviewing or developing a scenario.

The QA/QC Scenario Team continues to review and modify available nonstandard scenarios as the need arises. However, the team's primary function is to QA/QC scenarios modified and developed by EFED staff. Current team members are Sid Abel (Team Lead), Jim Wolf, Kevin Costello, and Ian Kennedy. When the need arises, you may contact a team member for assistance.

Tier 2 Turf Model

In 2001 the Water Quality Technical Team (WQTT) formed a subgroup to investigate the development of a Tier 2 model for assessing exposures from pesticides used on turf and golf courses. The subgroup has completed this activity, developing two evaluated scenarios employing the PRZM modeling program to estimate loadings to the EXAMS pond or reservoir environment. The major component of the evaluation process was to compare available monitoring data for several pesticides across a range of fate properties to the results of a modified PRZM field crop scenario to account for the differences in the uppermost soil layer typical of turf grass and/or golf courses.

Following the workgroups efforts, the approach was presented to the WQTT for peer review. The last attachment to this memorandum contains the assessment conducted by the subgroup and endorsed by the WQTT evaluating the performance of the model. Modeling turf grass uses is to be performed using the current EPA Shell. Two PRZM turf modeling scenarios developed as a result of this effort are available on the LAN at:

F:\USER\SHARE\Models\Aquatic Exposure\PRZMEXAMS\Scenarios\STD_SCEN\QA_QC Standard Scenarios.

Scenario and Information Sources

The information referenced in this memorandum is available electronically on the LAN at the following locations:

QA/QC Standard PRZM Modeling Scenarios:

F:\USER\SHARE\Models\Aquatic Exposure\PRZMEXAMS\Scenarios\STD_SCEN\QA_QC Standard Scenarios

Non QA/QC Standard PRZM Modeling Scenarios:

F:\USER\SHARE\Models\Aquatic Exposure\PRZMEXAMS\Scenarios\STD_SCEN\Non-QA_QC Scenarios.

Documentation for Standard Scenarios including; QA/QC Procedure, Turf Modeling Evaluation, Standard Scenario Metadata File:

F:\USER\SHARE\Models\Aquatic Exposure\PRZMEXAMS\Scenarios\STD_SCEN\Standard Scenario Documentation

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Table 1. QA/QC Crop Scenarios (10/22/01)

STATE	CROP	MLRA[1]	SOIL	Benchmark[2] (94 or 99 listings)
CA	Alfalfa	17/18	Sacramento	Yes
CA	Citrus	17	Exeter	Yes
CA	Corn	18	Madera	
CA	Cotton	17	Twisselman	
CA	Fruit (non-citrus)	17/18	Exeter	Yes
CA	Grape	17/18	San Joaquin	Yes
CA	Sugarbeet	17/18	Exeter	Yes
CA	Tomatoes	17/18	Stockton	
CA	Walnuts/Almonds	17/18	Mateca	
FL	Cabbage	156B	Riviera	Yes
FL	Citrus	156A	Wabasso	Yes
FL	Cucumber	156B	Riviera	Yes
FL	Sugarcane	156A	Wabasso	Yes
FL	Sweet Corn	156B	Riviera	Yes
FL	Turf	156A	Adamsville	
IL	Corn	108	Adair	
LA	Sugarcane	131	Commerce	Yes
MN	Alfalfa	56	Bearden	Yes
MN	Sugarbeet	56	Adair	
MS	Corn	134	Grenada	Yes
MS	Cotton	131	Loring	Yes
MS	Soybean	134	Loring	Yes
NC	Alfalfa	130	Helena	
NC	Apple	130	Hayesville	Yes
NC	Corn - E	133A	Craven	
NC	Corn - W	130	Chewacla	
NC	Cotton	133A	Boswell	
NC	Peanut	130	Craven	
NC	Tobacco	133A	Norfolk	Yes
ND	Corn	56	Bearden	Yes
ND	Wheat	56	Bearden	Yes
OR	Apple	2	Cornelius	
OR	Berries	2	Woodburn	Yes

STATE	CROP	MLRA	SOIL	Benchmark (94 or 99 listings)
OR✓	Christmas Trees	2	Pilchuck	Yes
OR ✓	Filberts	2	Cornelius	
OR✓	Grass Seed	2	Dayton	Yes
OR✓	Hops	2	Woodburn	Yes
OR✓	Mint	2	Newberg	
OR ✓	Sweetcorn	2	Woodburn	Yes
OR ✓	Vegetable (non-tuber)/Snapbea ns	2	Dayton	Yes
OR ✓	Wheat	2	Bashaw	Yes
PA ✓	Alfalfa	148	Glenville	Yes
PA✓	Apple	148	Elioak	Yes
PA✓	Corn	148	Hagerstown	Yes
PA ✓	Turf	148	Gkenville	Yes
PA✓	Vegetable /tomatoes	148	Glenville	Yes
TX✓	Alfalfa	87	Lufkin	Yes
TX✓	Corn	87	Axtell	Yes
TX✓	Cotton	86	Crockett	Yes
TX ✓	Sorghum	87	Axtell	Yes
TX ✓	Wheat	86	Crockett	Yes

[1]MLRA: Major Land Resource Areas. Land resource units are geographic areas, often extending for thousands of acres, that are characterized by common patterns of soil, climate, water resources and the use of the land. Land resource units are the basic elements from which the USDA Soil Conservation [illegible]ice (SCS) determined Major Land Resource Areas (MLRA). MLRAs are geographically related land resource units. The USDA Soil Conservation Service identified these and also their next higher grouping, Land Resource Regions, based on the same but broader factors. http://edcwww.cr.usgs.gov/glis/hyper/guide/mlra#mlra1

[2]Benchmark Soil: A benchmark soil is one of large extent, one that holds a key position in the soil classification system, one for which there is a large amount of data, or one that has special significance to farming, engineering, forestry, ranching, recreational development, urban development, wetland restoration, or other uses. http://www.statlab.iastate.edu/soils/nssh/630.htm

Table 2. Existing Scenarios Needing QA/QC

State	Crop	MLRA	Weather Station
CA	Kiwi	17	Bakersfield, CA (W23155)
CA	Onion	17	Bakersfield, CA (W23155)
CA	Cabbage Coastal	14	San Francisco, CA (W23234)
DE	Tomato	153C	Wilmington, DE (W13781)
FL	Tomato	156A	Miami, FL (W12839)
FL	Strawberry	154	Orlando, FL (W12841)
GA	Corn	137	Augusta, GA (W03820)
GA	Sweetcorn	133A	Montgomery, AL (W13895)
GA	Soybean	133A	Montgomery, AL (W13895)
GA	Peach	133A	Montgomery, AL (W13895)
GA	Pecan	138	Tallahassee, FL (W93805
GA	Peanut	153A	Wilmington, NC (W13748)
GA	Tobacco	133A	Montgomery, AL (W13895)
IA	Corn	108	Burlington, IA (W14831)
ID	Potato	13	Landen, WY (W24021)
KS	Sorghum	112	Tulsa, OK (W13968)
KS	Corn	112	Tulsa, OK (W13968)
LA	Sweetpotato	134	Little Rock, AR (W03963)
ME	Potato	143	Burlington, VT (W14742)
MI	Bean	99	Detroit, MI (W94826)
MI	Blueberry	97	South Bend, IN (W14848)
MI	Cherries	96	Muskegon, WI (W14840)
MN	Corn	105	Rochester, MN (W14925)
MN	Pasture/Hay	91	Minneapolis, MN (W14922)
ND	Sunflower	55B	Sheridan, WY (W24029)
	Canola	55A	Billings, MT (W24033)
NE	Corn	107	Omaha, NE (W14942)
NE	Corn	71	Grand Island, NE (W14935)
NJ	Tomato	149A	Philadelphia, PA (W13749)
NY	Apple	144B	Albany, NY (W04725)
NY	Cabbage	140	Binghamton, NY (W14735)
NY	Grape	100	Erie, PA (W14860)
NY	Grape	140	Binghamton, NY (W14735)
OH	Corn	111	Vandalia, OH (W93815)
OK	Sorghum	112	Tulsa, OK (W13968)
OR	Alfalfa	23	Pendleton, OR (W24155)
OR	Hops	2	Salem, OR (W24232)
OR	Pears	2	Salem, OR (W24232)
OR	Plums	2	Salem, OR (W24232)
OR	Strawberry	2	Salem, OR (W24232)
OR	Walnuts	2	Salem, OR (W24232)

Table 2. Existing Scenarios Needing QA/QC

State	Crop	MLRA	Weather Station
PA	Corn	148	Allentown, PA (W14737)
PA	Potato	149A	Philadelphia, PA (W13749)
SD	Springwheat	102A	Sioux Falls, SD (W14920)
TN	Broccoli	130	Bristol, TN (W13877)
TN	Lettuce	~~130~~	Bristol, TN (W13877)
TX	Broccoli	83D	Brownsville, TN (W12919)
VA	Barley	136	Athens, GA (W13873)
WI	Cherry	96	Muskegon, WI (W14840)

Development of a Modeling Approach to Estimate Runoff of Pesticide Residues from Managed Turf Grass

The EFED turf modeling workgroup: Jim Carleton (Team Lead), Jim Lin, and Mark Corbin

Objectives: The objective for the immediate future is to develop modeling scenarios for the OP aggregate/cumulative assessment process, and for routine EFED use for other chemicals, that can be employed with current versions of PRZM and EXAMS to estimate runoff of pesticide residues from turf. Longer term objectives include possible modifications of PRZM code to allow the model to better handle the thatch layer, and development of postprocessing tools to allow the summation of loadings from various separate golf course features (*i.e.* fairway runoff, tee runoff, green runoff and leachate) to surface waters.

Background: EFED uses the Pesticide Root Zone Model (PRZM) to simulate pesticide runoff and leaching. PRZM simulates two zones in an agricultural field — the cropped zone and the soil zone. The cropped zone includes the region above the land surface. The soil zone includes the region below the land surface. Turf, unlike most agricultural crops, can have a third important zone: the thatch zone. The thatch zone is located between the cropped zone (grass) and the soil. Thatch is made up of dead, undecomposed grass leaf and root material. Thatch may be important in turf modeling because it possesses hydrologic and pesticide fate properties which may differ significantly from the other two zones described above. The thatch zone may strongly influence movement of both water and pesticide from the surface into the soil. Correctly representing the properties of the thatch zone is therefore important to simulation of pesticide runoff and leaching from turf areas.

Interim Scenario Development: In order to meet the short-term objectives described above, the team revisited a modeling approach developed by Jim Lin at Bayer in the early 1990's (MRID 43256309) which employed the existing version of the model (PRZM 1). This involved treating thatch within PRZM as a 2 cm. layer of "soil" on top of an actual soil profile, similar to an approach later used by Duborow *et al.* (2000) to model pesticide runoff from turf. The following critical thatch properties needed to model it as soil were obtained from a published laboratory study (Hurto *et al.*, 1980) on Kentucky bluegrass thatch: bulk density = 0.37; field capacity = 0.47; wilting point = 0.27; organic carbon = 35.6%. Results from a small turf plot runoff study were used to back-calculate a curve number for the site, and PRZM was run to simulate the runoff of pesticides under the artificial rainfall conditions of the study. Differences between modeled total pesticide runoff loads and measured loads leaving the four plots ranged between -27.4% and 34.5%, indicating good agreement between model predictions and data.
A key consideration in modeling thatch as a soil layer is the selection of an appropriate value for % organic carbon (%OC). Although thatch has a very high organic carbon content, pesticide sorption to organic carbon in thatch is not well characterized by the results of sorption studies conducted in soils. Several studies which have examined and compared Koc values for pesticides in thatch and in soil have found lower Koc values in thatch (*e.g.* Dell *et al.*, 1994; Lickfeldt *et al.*, 1995). This may be due to the relatively undecomposed nature of the organic matter in thatch, and resultant differences in hydrophobicity of carbon in thatch as compared to soil.
Unfortunately, EFED does not typically have studies of pesticide sorption on thatch to develop

model inputs and must make due with sorption coefficients derived from studies on soil. The suggested approach is this: in the absence of thatch-based Koc values, soil-based Koc values can be used to model thatch sorption by lowering the %OC in the modeled thatch until the sorptive characteristics empirically match the results obtained in small plot runoff studies.

Small plot studies used to calibrate effective %OC in thatch: The results of published studies conducted in the piedmont region of Georgia (Song and Smith, 1997; Smith and Bridges, 1996) were found to contain sufficient detail to allow PRZM calibration, as described above, for purposes of calculating a value for effective %OC in the thatch layer. These studies involved small-plot simulated golf course fairways (planted in bermudagrass) to which 2,4-D, dicamba, mecoprop, and dithiopyr were applied. The soil at the site is described as a Cecil sandy clay loam. Following applications on various dates, simulated rainfall of known volume (2.5 to 5 cm) was applied on days 1,2,4, and 8 after application. Total water volume leaving the plots after each artificial rainfall was reported in one study (Smith and Bridges, 1996). Total pesticide load leaving the plots in runoff was reported in both studies.

In order to model these applications and runoff events, the meteorologic file for the region (MRLA 136) was altered to include these "rainfall" additions on the specified dates (arbitrarily in the years 1956 and 1957, since the met file does not include data beyond 1983, and the actual applications took place in 1993 and 1994). The soil profile in the PRZM input file was developed as described above, with soil layer thicknesses and properties for a Cecil sandy clay loam obtained from the DBAPE database, and a 2 cm thick layer of "thatch" on top as described above. Application rates and dates were set to match those of the actual applications. The foliar extraction coefficient (0.5) and pesticide fate properties were set in accordance with current input parameter guidance. Maximum rooting depth was set at 3 cm. The model was run using various trial values of curve number (CN) until the total volume of runoff matched the observed volume reasonably well (Figure 1), which occurred with a CN of 93.

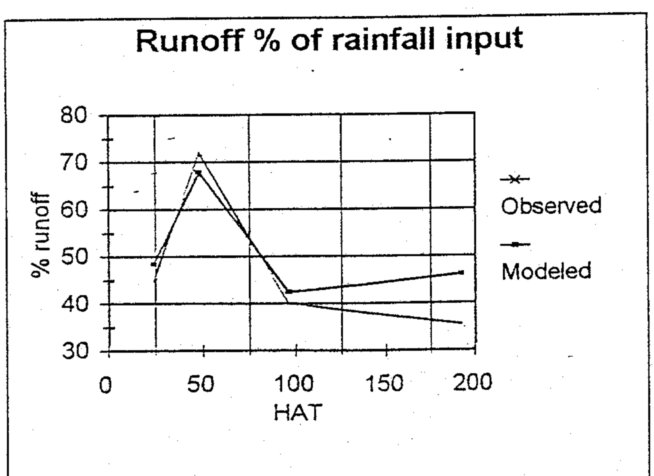

Figure 1. Modeled vs. observed runoff at Georgia small plot turf runoff study, shown as a function of hour after treatment (HAT).

With the CN set at 93, PRZM was then run using various trial values of %OC in the thatch layer to model two compounds with high and low mobilities: 2,4-D (Koc=34.23) and dithiopyr (Koc=1920), respectively. By trial and error, a value of 7.5% OC was found to result in good agreement between model predictions and data for both compounds (Figures 2,3,4). Results for two compounds modeled using Kd rather than Koc (dicamba, Kd=0.07; and mecoprop, Kd=0.29) also matched data reasonably closely (Figures 5, 6).

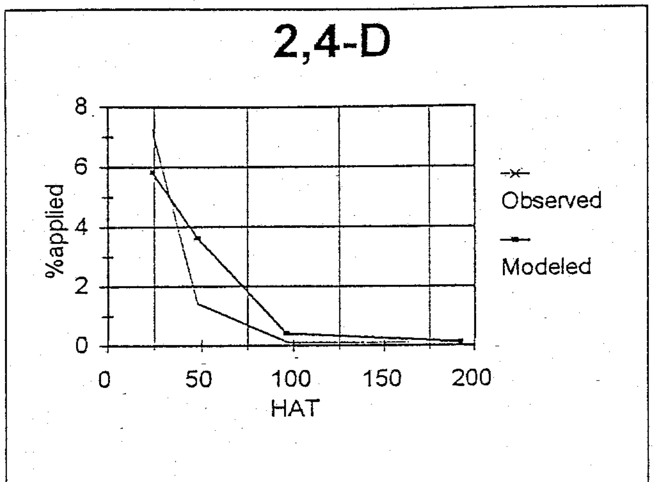

Figure 2. Modeled vs. observed 2,4-D runoff loading at Georgia small plot turf runoff study, shown as a function of hour after treatment (HAT).

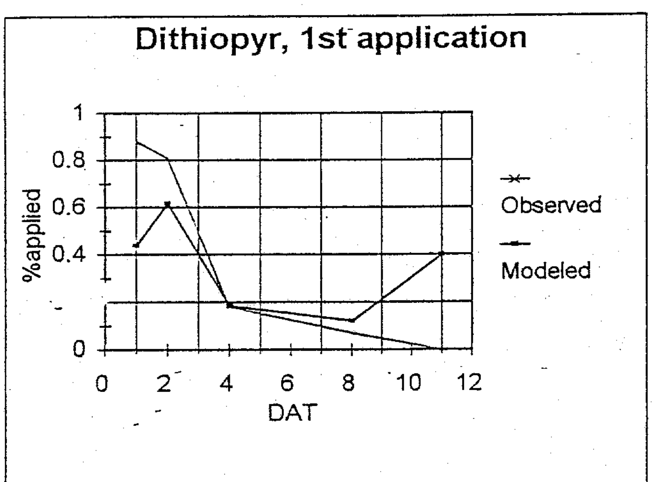

Figure 3. Modeled vs. observed dithiopyr runoff loading at Georgia small plot turf runoff study (first application), shown as a function of days after treatment (DAT).

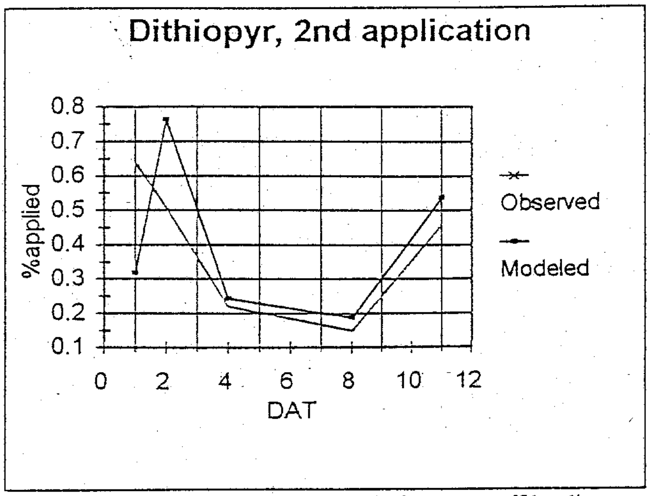

Figure 4. Modeled vs. observed dithiopyr runoff loading at Georgia small plot turf runoff study (second application), shown as a function of days after treatment (DAT).

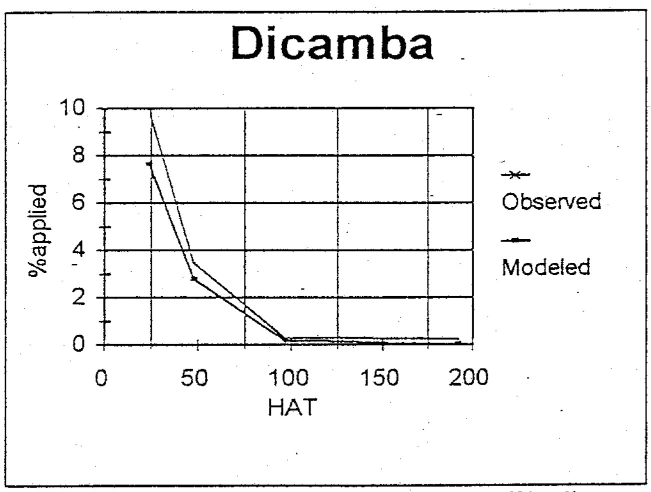

Figure 5. Modeled vs. observed dicamba runoff loading at Georgia small plot turf runoff study, shown as a function of hour after treatment (HAT).

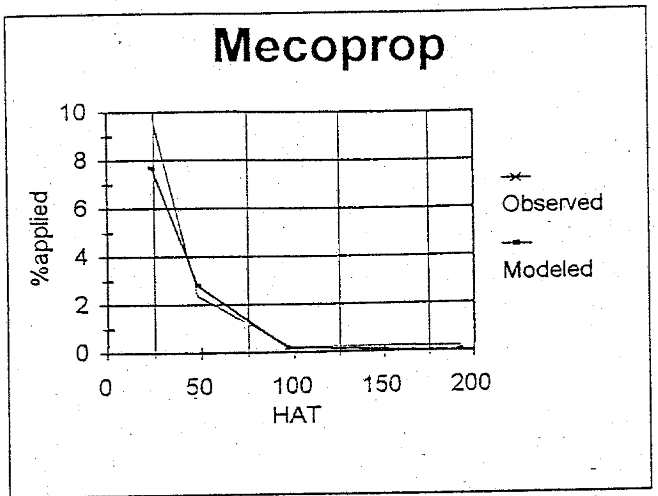

Figure 6. Modeled vs. observed mecoprop runoff loading at Georgia small plot turf runoff study, shown as a function of hour after treatment (HAT).

Other simulations: Given the above modeling results, turf scenarios have thus far been developed for two specific geographic regions, with thatch modeled as a 2 cm layer of "soil" containing 7.5% OC, over soil profiles developed based on information in the DBAPE database.

Madison, Wisconsin A Plano silt loam was selected to represent the region, because it is the hydrologic group B soil with the highest acreage in Dane County, WI (there are no group C or D soils in Dane county). MLRA 95b was selected arbitrarily to represent the meteorology for the scenario, although Dane county appears to be roughly equally divided between MLRA 95b and MLRA 105. A curve number of 61 was chosen in accordance with TR-55 guidance for "good condition" open space (lawns, parks, golf courses) on hydrologic soil group B (USDA, 1986). Full 36-year simulations of the farm pond using PRZM and EXAMS were run for 2,4-D and diazinon using this scenario. Applications of both compounds were modeled as taking place at the maximum rates on June 15 and July 15 every year. The resulting upper 90th percentile peak concentrations were 9.0 ppb and 11.4 ppb for 2,4-D and diazinon, respectively. These results are in reasonable agreement with concentrations documented by Bannerman *et al.* (1996) in suburban Madison stormwater ponds between 1989 and 1994: 10 ppb and 2.2 ppb for 2,4-D and diazinon, respectively.

Myrtle Beach, South Carolina A scenario was developed for this region because it is known to contain a high percentage of golf course acreage. A Johnston mucky loam was selected to represent the region because it is the hydrologic group D soil with the highest acreage in Horry County, SC. The MLRA for the region is 153b, and a curve number of 80 was selected in accordance with TR-55 guidance for "good condition" open space on hydrologic soil group D. A full 36-year simulation of the farm pond using PRZM and EXAMS was run for 2,4-D using this scenario. Application was modeled as taking place at the maximum rate on May 15 and June 15 every year. The resulting upper 90th percentile peak concentration was 23.9 ppb. For comparative purposes, the maximum concentration of 2,4-D in surface water measured by the NAWQA program was 15 ppb, found in the Trinity river basin of Texas (Land *et al.*, 1998). The NAWQA program has not established a sampling unit in South Carolina.

Summary of Proposed Approach: The interim approach suggested for developing scenarios for modeling pesticide runoff from turf is to select soils (and their properties) for the region in question just as one would do when developing a standard agricultural scenario. A 2 cm deep layer of "thatch" is added on top of this soil profile, with the following properties: bulk density = 0.37; field capacity = 0.47; wilting point = 0.27; organic carbon = 7.5%. Curve numbers are selected based on "good condition" open space areas as specified in TR-55, that is 39, 61, 74, and 80 for hydrologic soil groups A,B,C, and D, respectively. A 2 cm layer of thatch is typical for golf course fairways, but is probably thicker than average for golf course greens (Mike Kenna, personal communication). Modern greens built according to current USGA specifications are designed to rapidly infiltrate water, and are built upon sand/peat mixtures, with tile underdrainage. However, a large fraction of the greens in this country are of the old-style "push-up" variety, composed essentially of existing soil from the site, and lacking underdrainage. For preliminary modeling purposes, turf will be considered to be essentially generic, with no distinction made between fairways, greens, tees, or residential lawns. For chemicals applied to golf courses, the fraction of the total area composed of greens, tees, and fairways may however be used to modify the results of a modeling run, somewhat in the fashion of a percent cropped area (PCA) adjustment. The approximate average percent areas (confirmed by Mike Kenna, USGA, personal communication) are as follows: fairways, 23%; greens, 2%; tees, 2%. Thus if a pesticide is only used on greens and tees, for example, the modeling results would be multiplied by a factor of 0.04. It is possible that current PCA development efforts may produce PCAs for golf courses, turf farms, and/or residential lawns that may also be used to refine the results of modeling runs.

REFERENCES

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